IMPORTANCE OF RELATIVE HUMIDITY AND TEMPERATURE CONTROL IN CONDITIONING WOOD PRODUCTS[1]

William T. Simpson

Forest Products Laboratory,[2] Forest Service, U.S. Department of Agriculture, Madison, WI 53705

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ABSTRACT

Equilibrium moisture content of solid wood and reconstituted wood is analyzed to determine the level of relative humidity and temperature control necessary to maintain EMC within desired limits during conditioning. The necessary degree of control is found to be highly dependent on relative humidity and temperature.

Keywords: Equilibrium moisture content, water absorption, conditioning, wood products, plywood, particleboard, fiberboard, hygroscopicity.

INTRODUCTION

Wood and wood products are often conditioned to various levels of constant moisture content. In production it is often desirable or necessary to store solid or reconstituted wood products at optimum moisture content conditions while awaiting further fabrication into final products, or to store the final products themselves. In certain stages of many drying operations, it is necessary to control temperature and relative humidity so that conditions of constant moisture content are maintained. In research and testing, moisture content must often be a controlled variable because of the dependence of so many properties of wood on moisture content.

Relative humidity and temperature are the principal variables that affect the equilibrium moisture content (EMC) of wood. To hold a conditioning environment within any given tolerance of EMC, it is necessary to know the effect of relative humidity and temperature on EMC. This information is well known for wood and to a somewhat lesser extent for reconstituted wood products. However, the quantitative information is not available in a form that one can quickly and easily use to determine the necessary control of the variables to control EMC conditions. The purpose of this paper is to assess the dependence of the EMC of wood on relative humidity and temperature in such a way that one can quickly determine what level of control is necessary to maintain EMC within desirable limits.

EMC DATA BASE

EMC data for solid wood are available in the *Wood Handbook* (1974) as a function of relative humidity and temperature. Suchsland (1972) has determined EMC data at 68 F for interior and exterior particleboards, and medium density fiberboard. Lee and Biblis (1976) have EMC data at 80 F for southern pine ply-

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[2] The Laboratory is maintained in cooperation with the University of Wisconsin.

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TABLE 1. *Parameters of Eq. 1 for EMC data for solid and reconstituted wood.*

Material	T	K_1	K_2	W
Simpson (1971)				
solid wood	80 F	5.76	0.7565	260.8
Lee and Biblis (1976)				
southern pine plywood	80 F	12.09	0.7937	318.5
Suchsland (1972)				
interior particleboard	68 F	46.91	0.7274	319.7
exterior particleboard	68 F	17.20	0.7532	364.4
medium density fiberboard	68 F	53.66	0.7433	390.5
McNatt (1974)				
tempered hardboard	80 F	15.92	0.7666	498.4

wood (3–5 plies). McNatt (1974) gave EMC data at 80 F for tempered hardboard, and in a test of thirty-five commercial hardboards (McNatt 1973) found a similar RH-EMC relationship.

The sorption of water by wood exhibits hysteresis—that is, for any given relative humidity, wood has a higher EMC during desorption than during adsorption. Differences sometimes reach several percent. EMC data should be accompanied by an explanation of whether it was determined in adsorption or desorption. The *Wood Handbook* data for solid wood have been termed "oscillating" sorption (Stamm 1964), which means that the EMC data fall about midway between adsorption and desorption values. Despite the ambiguity, this is a satisfactory way to represent data for many practical applications where relative humidity changes often fluctuate randomly up and down. Suchsland's data are for both adsorption and desorption. For the purpose of this analysis, intermediate values were estimated. The data of Lee and Biblis and McNatt are for adsorption only.

The analysis to be discussed later requires calculating slopes of curves, which can best be done from smooth functional relationships between EMC, relative humidity, and temperature. The tabulated EMC data of the Wood Handbook have been converted to a functional form (Simpson 1971):

$$m = \frac{18}{W}\left[\frac{K_1K_2h}{1 + K_1K_2h} + \frac{K_2h}{1 - K_2h}\right] \tag{1}$$

where

$$K_1 = 3.73 + 0.03642T - 0.0001547T^2 \tag{2}$$
$$K_2 = 0.674 + 0.001053T - 0.000001714T^2 \tag{3}$$
$$W = 216.9 + 0.01961T + 0.005720T^2 \tag{4}$$

and

m = moisture content (%)
h = relative humidity (%)
T = temperature (°F)

For the purpose of this paper, the EMC data of Suchsland and Lee and Biblis for reconstituted wood were fitted by least squares to Eq. 1. The parameters K_1, K_2 and W are listed in Table 1.

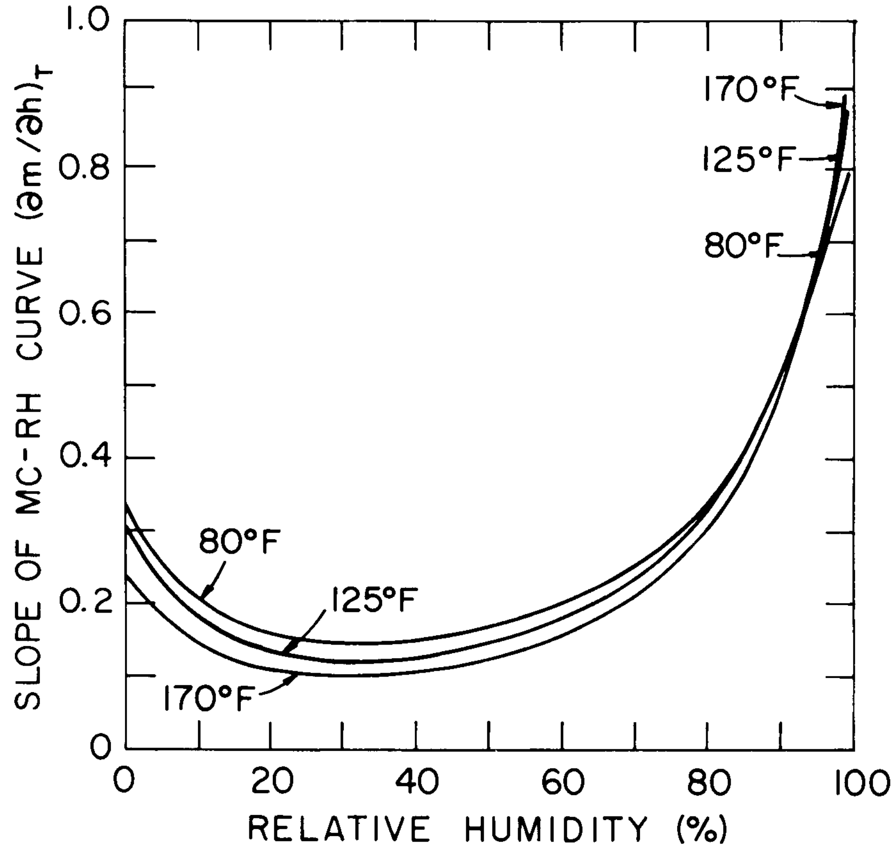

FIG. 1. Slope of moisture content-relative humidity curve versus relative humidity for solid wood at several levels of constant temperature.

ANALYSIS OF REQUIRED CONTROL

The ultimate goal of this analysis is to present information so that one can easily determine how closely relative humidity and temperature must be controlled to maintain EMC within desired limits. This cannot be done concisely because this level of required control is itself dependent upon relative humidity and temperature. For example, to maintain ±2% moisture content control at 90% relative humidity requires closer relative humidity control than is necessary to maintain ±2% moisture content control at 30% relative humidity. In other words, the rate of change of moisture content with relative humidity depends on relative humidity, and the rate of change of moisture content with temperature depends on temperature. Thus the analysis requires determination of the dependence of the rate of change of moisture content on these variables. In more precise terms, since

$$m = f(h, T) \tag{5}$$

it is necessary to determine the dependence of the slope of the moisture content-relative humidity (MC-RH) curve at constant temperature on relative humidity;

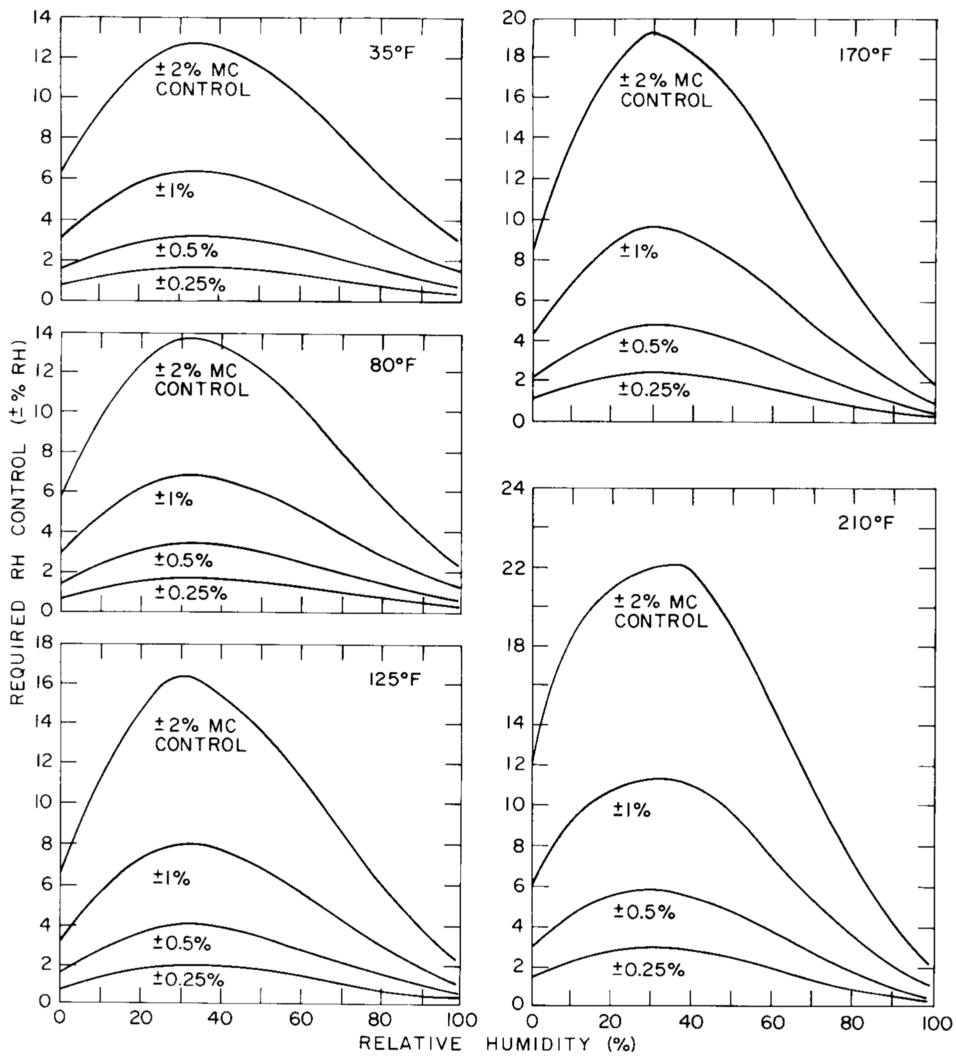

FIG. 2. Required RH control to maintain desired EMC control at all levels of relative humidity for solid wood at 35, 80, 125, 170 and 210 F.

$$\left(\frac{\partial m}{\partial h}\right)_T = f(h) \tag{6}$$

and the dependence of the slope of the moisture content-temperature curve at constant relative humidity on temperature;

$$\left(\frac{\partial m}{\partial T}\right)_h = f(T) \tag{7}$$

Differentiation of Eq. 1 with respect to *h* offers a convenient way to determine slopes of MC-RH curves. Because the use of Eqs. 1–4 to determine slopes of moisture content-temperature curves is cumbersome, numerical differentiation was employed.

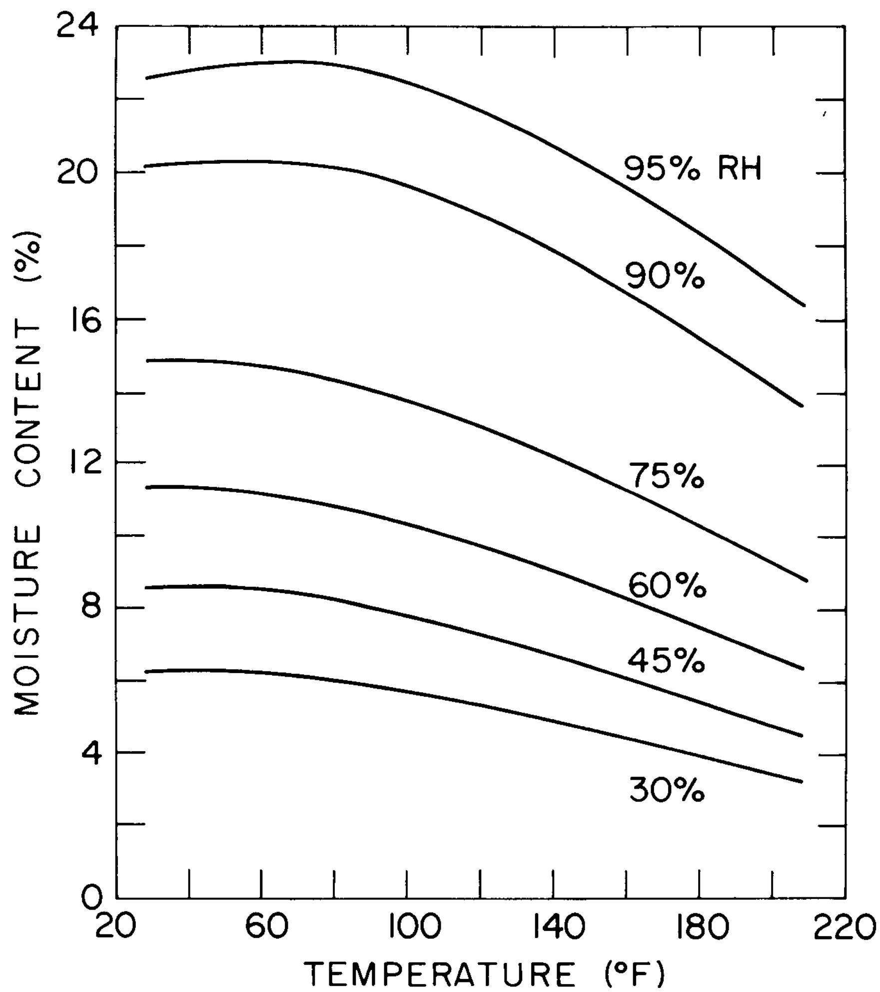

FIG. 3. Moisture content of solid wood as a function of temperature at constant relative humidity.

Solid wood

The slope of the MC-RH curve at constant temperature is shown (Fig. 1) as a function of RH at several levels of constant temperature. The minimum in the curves occurs at approximately 30% RH (or about 6% MC). At these minimums moisture content changes least with relative humidity, which means that to maintain EMC within certain limits RH need not be controlled as closely as would be necessary at other RH levels. At high levels of RH, close control becomes very important in maintaining EMC limits.

The information in Fig. 1 can also be presented directly in terms of the required RH control necessary to maintain given limits of EMC:

$$\text{Required RH control} = \frac{\text{desired MC control}}{(\partial m/\partial h)_T} \tag{8}$$

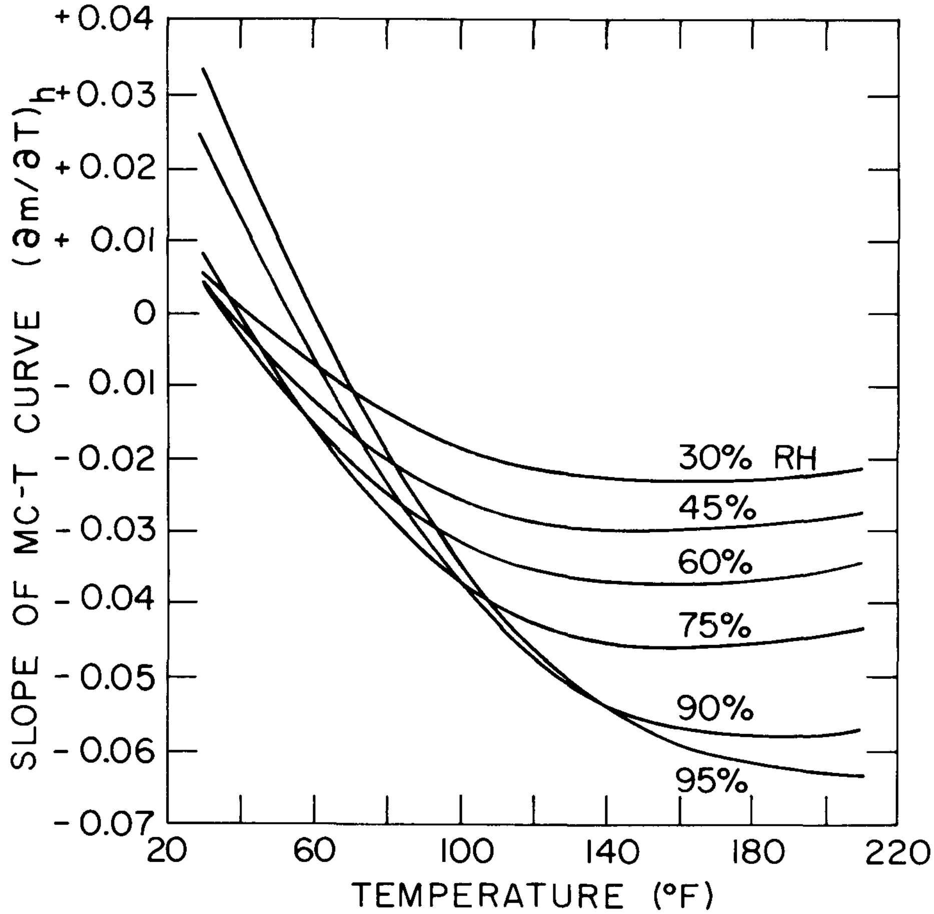

FIG. 4. Slope of moisture content-temperature curve versus temperature for solid wood at several levels of constant relative humidity.

For example, if one wants to maintain control of EMC conditions within ±1% MC at 80 F and 30% RH, it is necessary to control RH within approximately ±7% (Fig. 2). If one wants to control EMC within these same limits at 90% RH, it is necessary to maintain ±2% RH control. At high levels of RH, control must improve to maintain a given EMC tolerance.

A similar analysis was conducted for the temperature effect—that is, the temperature control (at constant RH) required to maintain EMC within certain limits. When plotted (Fig. 3), the graph is analogous to the sorption isotherm. The slopes of those curves can be shown (Fig. 4) as a function of temperature at several levels of constant RH. There is a reversal of the effect of T on MC: at low temperatures moisture content increases with temperature, but above 40–60 F, moisture content decreases with increasing temperature. Thus in the 40–60 F range, temperature has virtually no effect on the moisture content of solid wood.

The information in Fig. 4, too, can be presented directly in terms of the required temperature control necessary to maintain given limits of EMC:

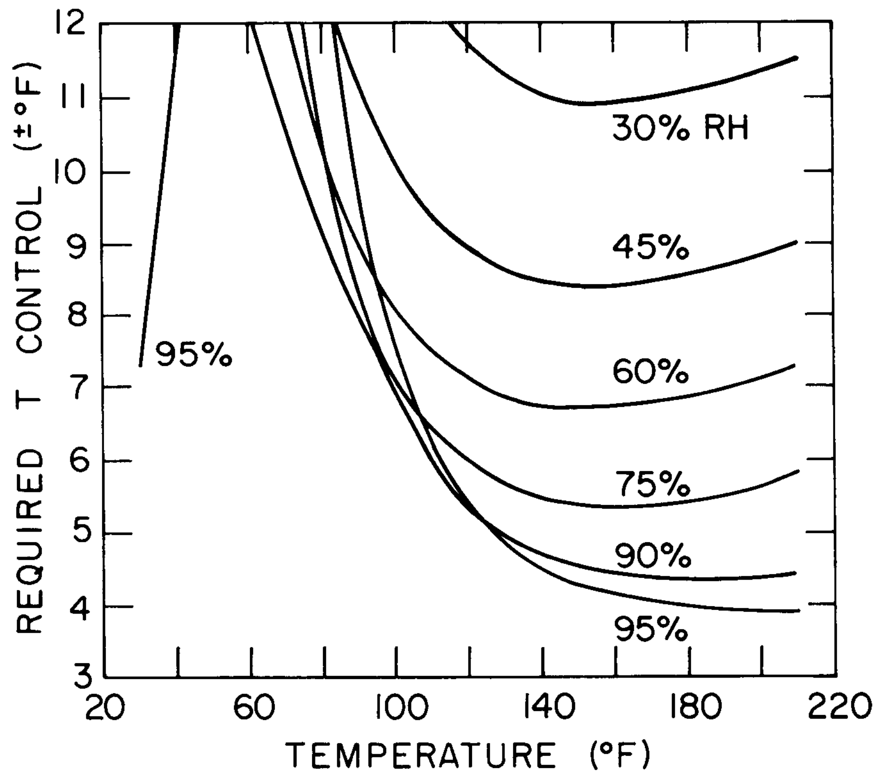

FIG. 5. Required temperature control to maintain EMC conditions across a range of temperatures for solid wood within ±0.25% MC.

$$\text{Required T control} = \frac{\text{desired MC control}}{(\partial m/\partial T)_h} \tag{9}$$

For example, at 75% RH and 120 F, temperature control need only be ±6 F to maintain EMC control with ±0.25% MC (Fig. 5). At room temperature (70–80 F), where much conditioning is done, required temperature control (at constant RH) can be quite poor and still maintain close EMC limits. This is near the temperature where the slope of the MC-T plot is zero and MC has little dependence on temperature.

Reconstituted wood

Data on the temperature dependence of the sorption isotherm for reconstituted wood are not available, so the analysis can only include required RH control. However, one could reasonably expect required temperature control to be similar to that for solid wood.

The dependence of the slope of the MC-RH curves on RH (Fig. 6) and the required RH control for EMC control (Fig. 7) are shown for southern pine plywood, interior particleboard, exterior particleboard, medium density fiberboard, and tempered hardboard. Comparison of these curves (Fig. 7) with the curve for

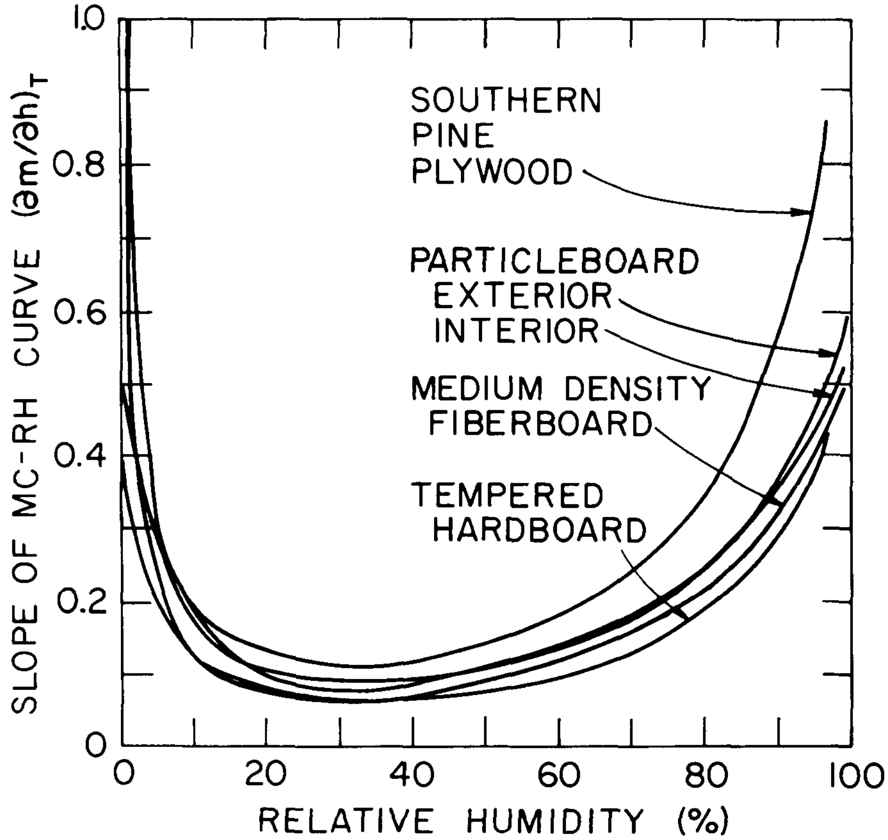

FIG. 6. Slope of moisture content-relative humidity curve versus relative humidity at constant temperature for reconstituted wood [from data of Suchsland (1972), Lee and Biblis (1976), and McNatt (1974).]

solid wood (Fig. 2) at 80 F shows the same general form—that is, peaks at about 30% RH where RH control can be quite poor, and the need for much better RH control at high levels of RH. It can be generally noted in comparing solid wood and reconstituted products that for any given level of desired EMC control, better RH control is required for solid wood than for reconstituted wood. As an example, consider the comparison between solid wood at 30% RH and 80 F and the reconstituted products at the same or nearly the same temperature (68 F). For ±1% EMC control, RH must be controlled within approximately ±7% for solid wood but only about ±9% for southern pine plywood, ±12.5% for interior particleboard, ±11% for exterior particleboard, and about 15% for both medium density fiberboard and tempered hardboard.

SUMMARY

An analysis is presented to determine the levels of relative humidity and temperature control necessary to maintain the EMC of solid and reconstituted wood within certain prescribed limits during conditioning. Relative humidity has a larger effect on EMC than does temperature and its control in conditioning is therefore

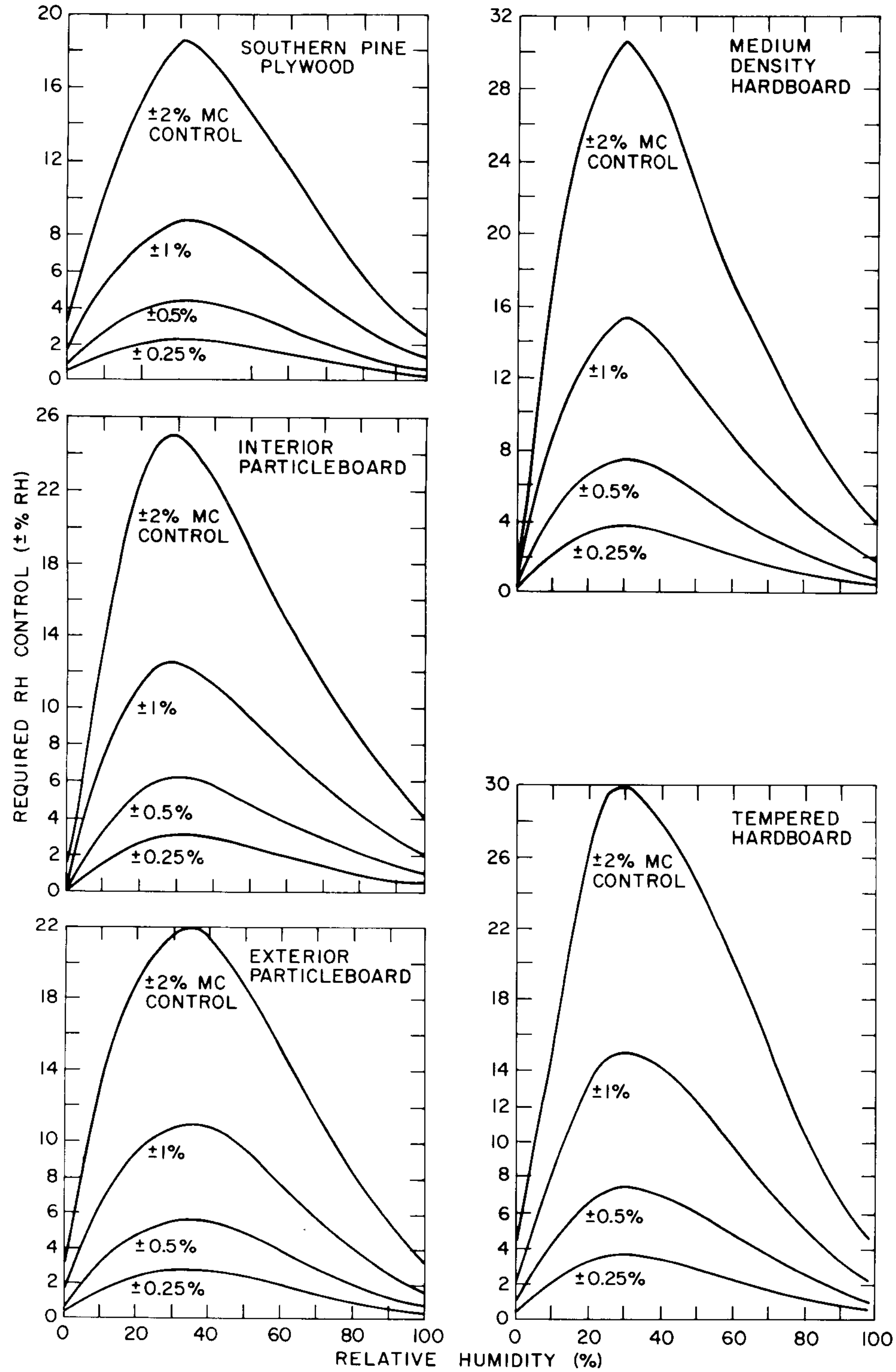

FIG. 7. Required RH control to maintain desired EMC control at all levels of relative humidity for reconstituted wood products.

more important. Required relative humidity control is dependent on the level of relative humidity. At high levels of RH, control must be much better than at mid-range RH's to maintain the same level of EMC control. Similarly, required temperature control is dependent on the level of temperature. In the range of approximately 40–60 F, temperature has very little effect on MC, and thus temperature control has little significance in conditioning to an EMC. Required temperature control becomes closer up to approximately 120 F where it begins to level off. For equal EMC control, solid wood requires slightly better RH control than does reconstituted wood.

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